Appendix V : Landuse Planning

The purpose of this application was to simply illustrate the effective use of GIS and landuse mapping for decision making and project planning. The objective of the study was to evaluate the introduction of two land degradation alleviation interventions, reforestation and agroforestry. Given the rapid rates of deforestation, increasing populations and the ever increasing need for farming inputs such as fertilizers, there is a need to evaluate alternative strategies to address such issues as diminishing fuel wood supply, increased soil loss and reductions in water quality. Given the two courses of action to be evaluated, GIS can assist to identify the most suitable locations for each strategy. In order to increase fuelwood stocks, reduce soil loss, and reduce fertilizer runoff into streams, for example, decision makers have made the decision to target appropriate areas based on proximity to streams, and, the degree of slope. The table below summarizes the sample strategies. GIS can now be used to solve for these strategies and identify those areas most suited for each.

	Near Streams (< 50 m)	Away from Streams (> 50 m)
Low Slopes (< 5 %)		
Moderate Slopes (5 - 9 %)	Agroforestry (if cultivated)	
High Slopes (9 - 12 %)	Reforestation	Agroforestry (if cultivated)
Extreme Slopes (> 12 %)	Reforestation	Reforestation

The first step in the analysis is to create a landuse map. Figure 1 shows a landuse map for Kamunde catchment, one of the catchments under MEMP located in Mangochi and adjacent to the Phirilongwe Forest Reserve. The landuse map was made using image processing techniques and SPOT 20 meter satellite data. Next, using topographic data produced for the catchment by the Department of Surveys (DOS) and later digitized by Lands Resources and Conservation Branch (LRCB), a slope hazards map was produced that corresponds to the categories used in the table above (Figure 2). DOS also supplied the mapped data on the streams which were used to produce 50 meter buffers zones around each (Figure 3). Through further GIS analysis appropriate landuses were identified and evaluated using our example criteria of slopes and stream proximity and its appropriate strategy corresponding to the table above (Figure 4). Further, with the current landuse of the catchment, areas can readily be identified that are currently inappropriately employed given our strategy (Figure 5).

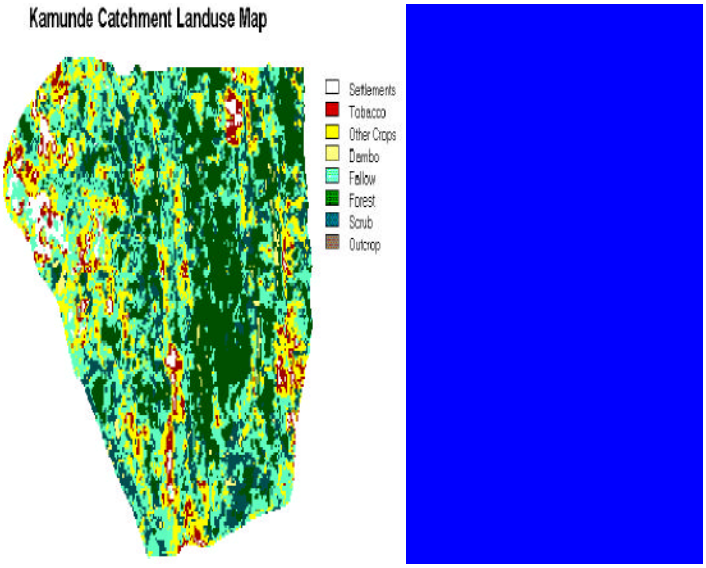


Figure 1 : Kamunde Catchment landuse map derived from SPOT 20 meter satellite imagery.

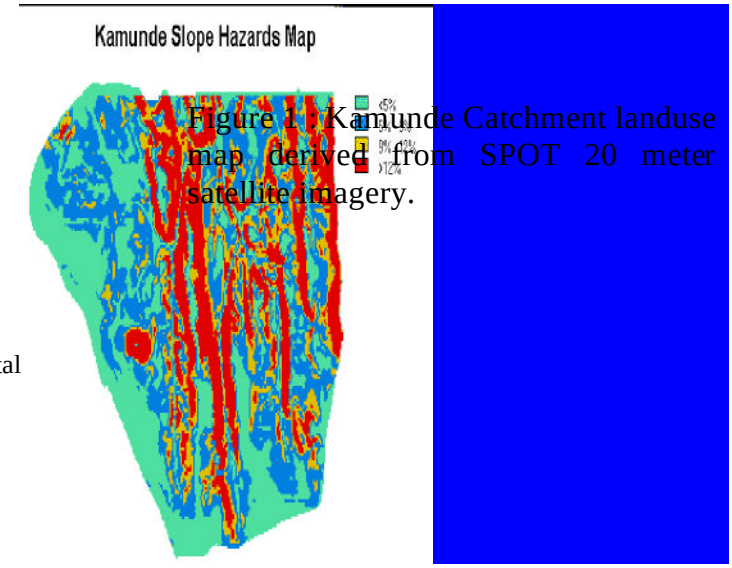


Figure 2 : Slope hazards map derived from digital elevation model supplied by DOS.

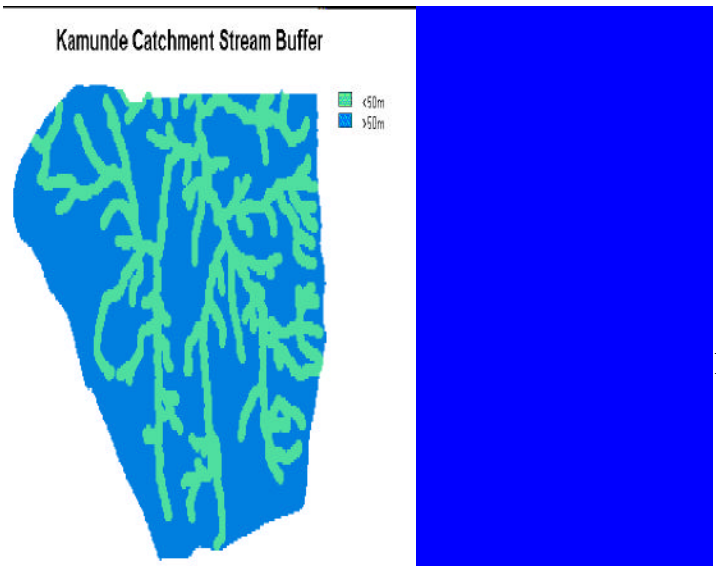


Figure 3 : 50 meter stream buffer map.

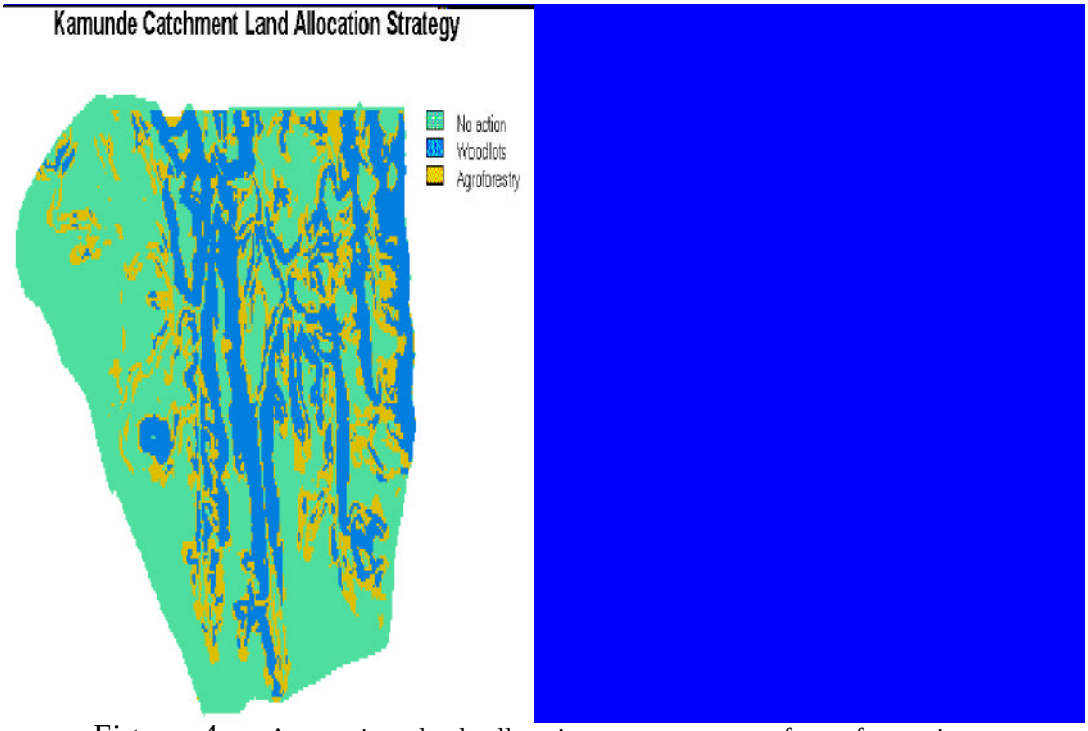


Figure 4 : Appropriate land allocation strategy map for reforestation or agroforestry initiatives.

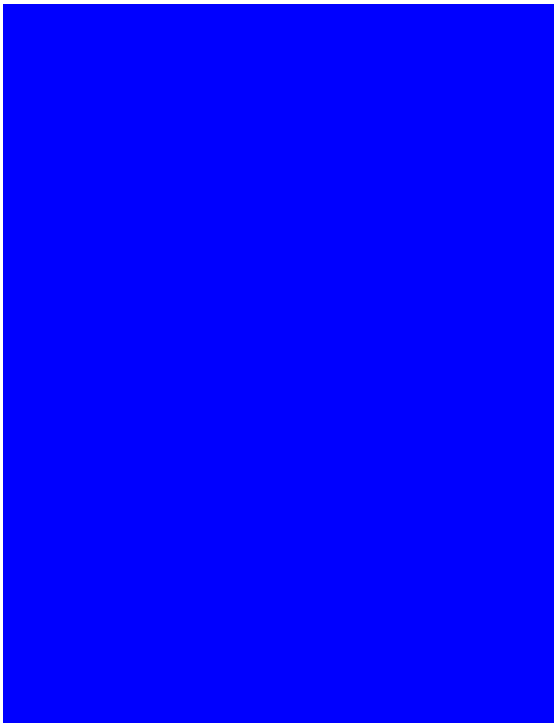


Figure 5 : Map indicating inappropriate landuses based on proposed landuse strategies.

Appendix VI : Rainfall Mapping Using Cold Cloud Duration (CCD) Data

This application illustrates the use of Cold Cloud Duration (CCD) data from the METEOSAT satellite for the purpose of improving rainfall mapping on a timely basis. At present, the Meteorology Department creates dekadal (10-day) rainfall maps by interpolating values between rain gauge stations. These maps are essentially approximations since the interpolation procedure is simply a controlled procedure for guessing what rainfall levels would be between rainfall gauges. With the CCD data, one has a mapping of the distribution of hours under clouds with upper surface temperatures lower than 40 degrees centigrade (Figure 1). Experiments have shown these data to be highly correlated with rainfall levels. With this project, CCD data were regressed against the rainfall data for Malawi for selected rainfall reporting stations (Figure 2). A strong correlation was found, and the procedures for regular production of rainfall maps (Figure 3) using this procedure are being performed at MET. Parenthetically, it should be noted that this procedure can be used to determine direct recharge of Lake Malawi. Until now, this has been impossible because of the absence of rain gauges on the lake. It also should be noted that the Meteorology Department currently receives CCD every 10 days from the Drought Monitoring Center in Harare.

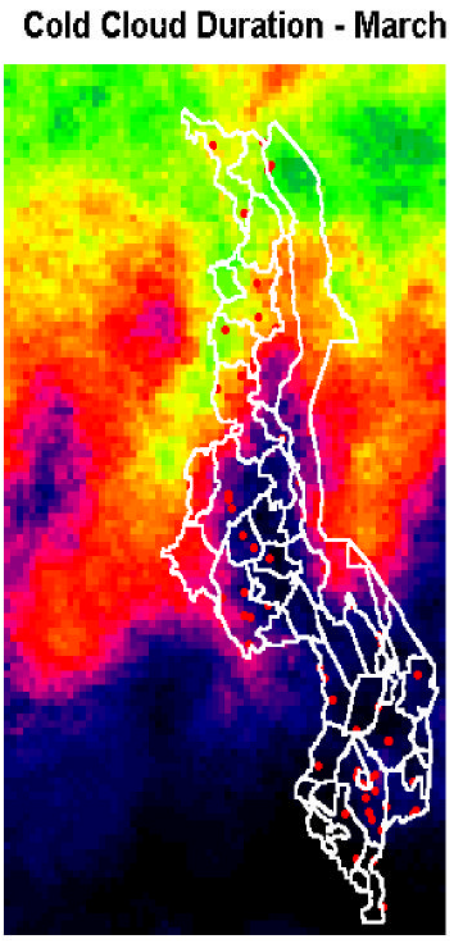


Figure 1

Map of Cold Cloud Duration data for South-Central Africa, including Malawi during March 1995. The Data ranges in total hours of cold clouds below 40 degrees centrigrade from zero hours in the south (black) to as high as 294 hours in the north (green)

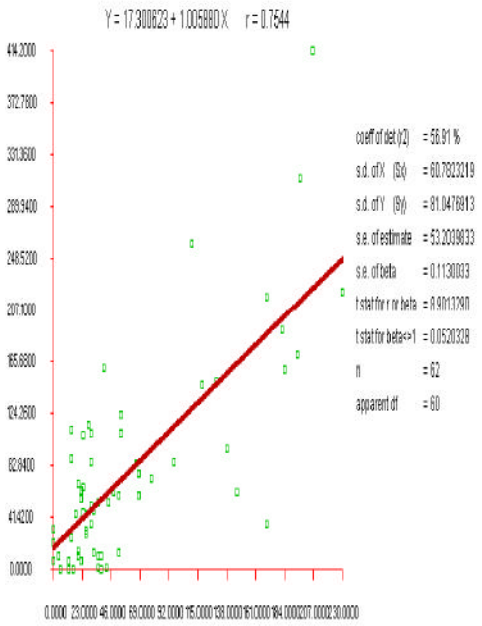


Figure 2 : Regression Analysis between CCD and mean annual rainfall for selected stations in Malawi, March 1995.

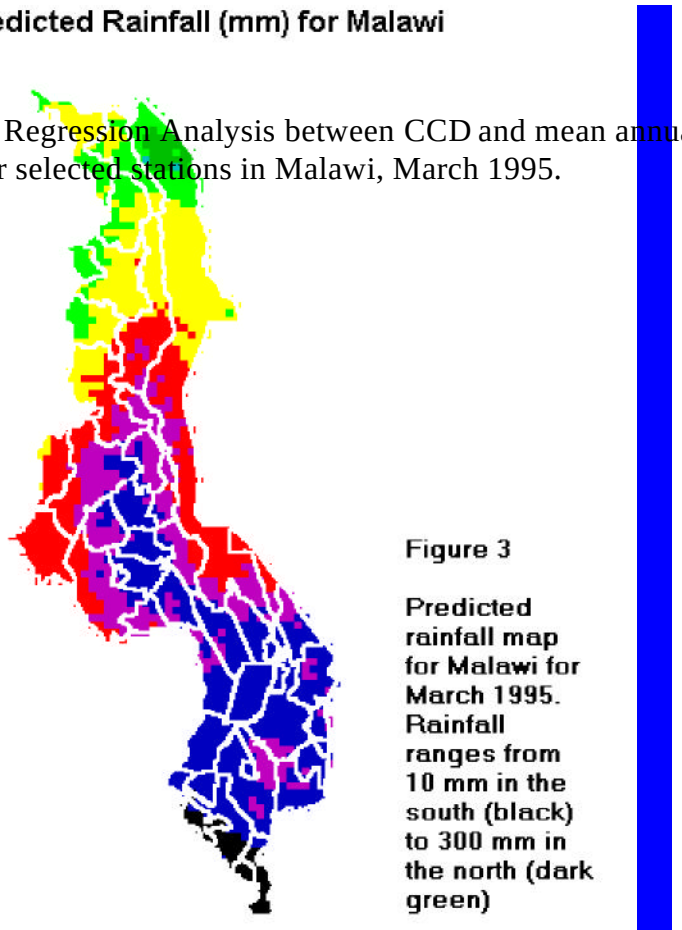
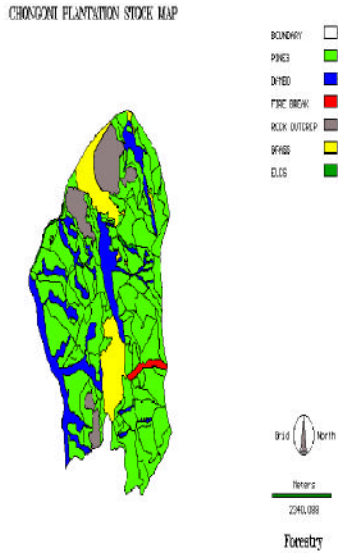


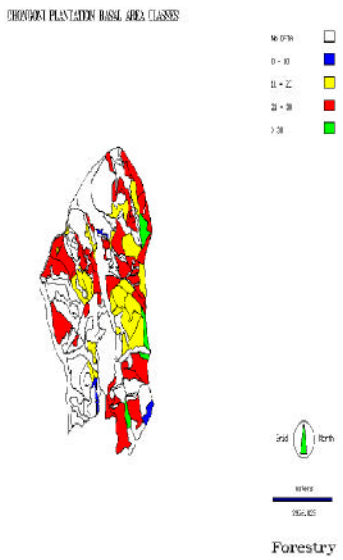
Figure 3

Predicted rainfall map for Malawi for March 1995. Rainfall ranges from 10 mm in the south (black) to 300 mm in the north (dark green)

Appendix VII : Forest Inventory Mapping

The mapping and management of Malawi's forest plantations was identified by the DOF as being vital for long-term forest management. The application project undertaken by the DOF demonstrates the use of GIS for forest inventory mapping for the Chongoni Plantation in Central Malawi. Using recent maps surveyed through traditional chain and compass and a database on the forest compartments, the plantation was digitized and imported in the GIS. The resulting maps demonstrate the database mapping capabilities of GIS for forest management.





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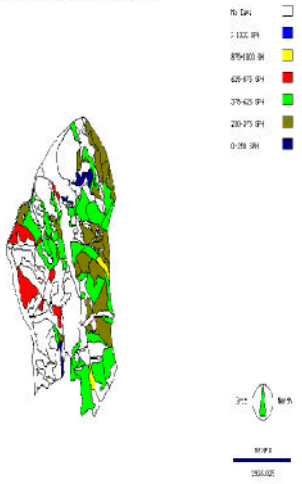
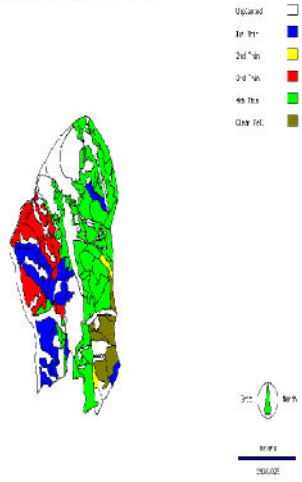


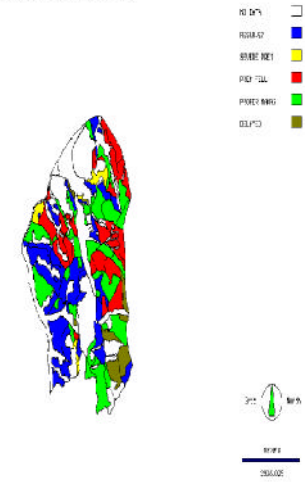
Forestry

CHONGOM PLANTATION MANAGEMENT SERIAL CLASSES



Forestry

CHONGOM PLANTATION MANAGEMENT



Forestry

Appendix VIII : Participants of the Decision Maker's Workshop

Name	Title	Agency
R.P. Chingoli	Senior Planning Officer	Ministry of Physical Planning and Surveys
A.F. Tambala	Surveyor General	Ministry of Physical Planning and Surveys
Z.D. Jere	Land Husbandry Officer	LRCB Mzuzu ADD
R.B. Muheya	Chief Cartographer	Survey Department
D.V.L. Naketo	Hydrologist	Water Department
P.W.R. Kaluwa	Senior Hydrologist	Ministry of Irrigation and Water
Dr. Chrissie Mwiyeriwa	PM Liwonde ADD	Liwonde ADD
Tressa Mandeule	Parks and Wildlife Officer	National Parks and Wildlife
Alex M. Banda	Chemist	Water Department
Susan Machila	Photogrammetrist	Survey Department
V.A.L. Mkandawire	Senior Land Husbandry Officer	Ministry of Agriculture and L/S Dev.
T.G. Mbale	Environmental Officer	Ministry of Research and Environmental Affairs
S. Kainja	Principal Forestry Officer	Forestry Department
W.K. Burger	MEMP Technical Advisor	Ministry of Research and Environmental Affairs
Dr. Danny Chinombo	Asst. Chief Veterinary Officer	Department of Veterinary Services
R.J.M. Mwakalagho	Ag. Asst. C.L.R.C.O.	LRCB

S.A. Mapila	**Deputy Director, Fisheries**	**Fisheries Department**
Steve Alimoso	**Senior Fisheries Res. Officer**	**Fisheries Department**
Maxwell Gwazantini	**Hydrometeorologist**	**Meteorology Department**
Orton M. Kachinjika	**Senior Fisheries Res. Officer**	**Fisheries Department**
C.M. Munthali	**Agrometeorologist**	**Meteorology Department**
E.R. M'mangsa	**Principal Environmental Offier**	**Ministry of Research and Environmental Affairs**
R.H. Manondo	**Deputy Secretary**	**Ministry of Research and Environmental Affairs**
A. Kamperewera	**Principal Environ.l Officer**	**Ministry of Research and Environmental Affairs**
Dr. J.R. Eastman	**Director, Clark Labs**	**Clark University**
J. Toledano	**Senior Res. Assoc., Clark Labs**	**Clark University**
W.M. Phiri	**Senior Environmental Officer**	**Ministry of Research and Environmental Affairs**
S.P. Kamwendo	**Chief Veterinary Officer**	**Deptartment of Veterinary Services**

Appendix IX : Agency Needs Assessment Checklist

The following is a summary of agency responses to a needs assessment survey given at the Decision Maker's Workshop.

Question	Department	Response
1. What is the overall mandate of your department?	Water	National administration and management of water resources; protection and distribution of portable clean water to communities
	MOREA	Facilitate and coordinate environmental management of Malawi
	Forestry	Promotion and management of forestry and trees
	Fisheries	Provide information for the management and development of fisheries; promotion of rural fish farming and training
	LRCB	Promotion of sustainable agriculture
	MET	Analysis, interpretation, and archiving of weather data and observations
	Survey	Preparation, revision and production of maps, plans and charts; delineate land holdings and national and international boundaries; provide survey controls for topographic mapping
2. What information products are required by decision makers in your department to reach above mandate?	Water	Water availability, quality, demand
	MOREA	Development plans and priorities; sectoral environmental policies; environmental and national resource use patterns
	Forestry	Distribution and location of existing stock; yield and demand trends
	Fisheries	Trends in fish yields; liminological, hydrographic and biological

	LRCB	Land resource potential (animal, crops, climate); germplasm; production systems, support services for markets, credit, training and extension
	MET	Weather forecasts, crop yield assessment, remote sensing and satellite imagery
	Survey	Land information and population data
3. What information products are supplied by your department to the Government of Malawi that are or can be used for environmental monitoring?	Water	Hydrological and water quality
	MOREA	National environmental policy, EIA guidelines and reports, environmental quality standards, environmental impact reports
	Forestry	Maps, reports on seed availability, nursery practices
	Fisheries	Fish yield and abundance, species comparisons and size, type of gear
	LRCB	Production systems, landuse information, erosion potential, agro-ecological information, crop suitability
	MET	Dekadal, monthly and season rainfall and agrometric bulletins, agrometric bulletins on food security
	Survey	Thematic maps, plans, charts and lake pilots
4. What is the frequency these products are needed in your department?	Water	Daily
	MOREA	Regularly and when needed
	Forestry	Monthly, quarterly, annually, five-year and snapshots
	Fisheries	Annually
	LRCB	Annual crop suitability, production calendars, landuse and erosion information, five-year agro-ecological data
	MET	Daily, 10-day, monthly
	Surveys	Continuously

5. What data are required to develop these products?	Water	Financial, capacity building, ministerial
	MOREA	Biophysical, socio-economic
	Forestry	Tree distance and location, existing stock, yield, satellite data and aerial photos
	Fisheries	Biological and ecological, liminological, hydrographic, fish statistics
	LRCB	Soil data, crop patterns, crop yields, land holdings, livestock statistics, pasture lands, rainfall, household size, aerial photos and satellite data
	MET	Rainfall and temperature data, NDVI and CCD data
	Survey	Field data, aerial photos, satellite imagery, statistical data, landuse data
6. Would GIS be an appropriate technology for your department in order to meet your department's overall responsibilities and mandates?	Water	Yes
	MOREA	Yes, for the establishment of an environmental information database
	Forestry	Yes, biomass loss, change detection and monitoring
	Fisheries	Yes, inventory and monitoring climate and sea surface
	LRCB	Yes, for landuse changes
	MET	Yes, for climate change and climate database
	Surveys	Yes, for land information systems
7. What additional training and staffing requirements would there be, if any, for implementation of GIS within your department to meet stated mandates?	Water	Data collection and project proposal development
	MOREA	Basic and specialist training
	Forestry	More training and trainees

	Fisheries	Creation of a national data center (environmental monitoring section) within Fisheries with career structures
	LRCB	Additional staff, sensitization of higher level decision makers, more trainings especially at the ADDs
	MET	More trainees and trainings in specialized areas
	Survey	More trainees and trainings in information technologies
8. What would be the possible barriers to using GIS technology within your department? What problems have you experienced thus far?	Water	More GIS experience, inconsistency of data
	MOREA	Software maintenance, hardware acquisition, inadequate technical and analytical skills, more user-friendly software
	Forestry	Amount of time dedicated to GIS, lack of support at higher levels within the department, technical support, training manuals and materials
	Fisheries	No staffing, training and equipment, finances, data
	LRCB	Financial, need more training of staff and equipment
	MET	Lack of hardware, compatibility of related softwares
	Surveys	Financial, personnel, hardware and software
9. Given the problems stated above, how would you measure success of GIS in your department?	Water	The development of applications and maps
	MOREA	Software and hardware acquisition, analytical and technical skill development
	Forestry	Support of decision makers, financial support for satellite imagery
	Fisheries	Already successful
	LRCB	Optimistic

	MET	Integrating with current activities
	Survey	Hardware and software acquisition

Appendix X : National Environmental Information Systems

This document was prepared as a discussion document for USAID and MOREA in April 1994, and proposes a structure for an EIS that was seen as a consistent development from the decentralized structure of the MEMP. Key elements of this structure included an overall multi-sectoral coordinating body, a National Mapping Program of coordinated digital data sets to support the application of GIS and related technologies and evolving educational program, and an information coordination and dissemination agency (most likely, MOREA itself).

The Malawi National Environmental Information System

A commentary and proposal prepared by

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The Clark Labs for Cartographic Technology and Geographic Analysis,
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in cooperation with

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University of Arizona

as a component of the

Malawi Environmental Monitoring Program
under funding provided by

The United States Agency for International Development
ARTS/FARA

April 18, 1994

Introduction

The multi-sectoral nature of most environment and natural resource problems requires the coordinated development of digital data sets that can be subjected to integrated analysis through the use of Geographic Information Systems (GIS) and related environmental information technologies. It is thus proposed that to support continued research and monitoring of environmental phenomena, a National Environmental Information System (EIS) be established. Such a system is consistent with the needs expressed in the Malawi National Environmental Action Plan (NEAP) and the current development of the Malawi Environmental Monitoring Program (MEMP) within the Department of Research and Environmental Affairs (DREA).

The Environmental Information System is intended to provide timely information to support the inventory, investigation, and monitoring of the environment. It is proposed that this be designed to consist of five subactivities:

1. ***EIS Coordinating Committee (ECC)***
2. ***National Environmental Mapping Program (NEMP)***
3. ***EIS Distribution Center (EDC)***
4. ***National Environmental Information Center (NEIC)***
5. ***National Program for the Development of Environmental Information Technologies (NPDEIT)***

These subactivities will provide the mechanism for the development, dissemination and use of a National Environmental Information Database. The database will consist of an off-line archive of coordinated datasets, developed through a distributed group of independent agency mapping activities, but accessed through a centralized body within the Department of Research and Environmental Affairs (DREA). At some future date, when the need becomes obvious, an on-line networked system can be considered. In the meantime, emphasis will be placed on the display and analysis of such data through the use of independent software and hardware

systems in a variety of contexts.

Organizational Structure

Figure 1 illustrates the proposed organizational structure of such a system. The EIS itself is enclosed in a red box, and can clearly be seen to be an inter-agency project, coordinated by the EIS Coordinating Committee (ECC). This committee is in turn responsible to the National Committee on the Environment (NCE) for overall policy guidance.

As can be seen in Figure 1, the EIS consists of environmental data (the boxes in the cyan color), and a support system consisting of a National Environmental Information Center (NEIC), an EIS Distribution Center (EDC) and a National Program for the Development of Environmental Information Technologies (NPDEIT). The first of these support systems provides information on what is available in the database and how to order it; the second distributes the data, and the third provides an educational framework for the procedures required to use these data in a cost-effective manner.

The data themselves come from two sources. The first, and most important, is a National Environmental Mapping Program. This consists of a set of independent, but coordinated, digital mapping activities by each of the main agencies producing spatially-referenced environmental data. The second is a more ad-hoc collection of reports and data sets produced by a range of government, non-government, academic and parastatal groups.

Components of the EIS

EIS Coordinating Committee

The EIS Coordinating Committee (ECC) will have responsibility for the overall design, implementation and management of the EIS. It should consist of a full-time secretary, and representatives from each of the key agencies involved. Responsibilities will include:

- *data model development for each element of the National Environmental Mapping Program*
- *development of accuracy, coding and documentation standards*
- *development of digital data exchange formats*
- *long-range planning for data acquisition*
- *coordination of long-range education and research in environmental information technologies*
- *coordination of long-range political and financial support*

Development of the first three of these elements will be strongly coordinated with the various mapping agencies involved. Indeed, the function of the ECC is largely to support and coordinate the activities of National Environmental Mapping Program Coordinating Committees within each of the affected agencies.

Although the ECC will be an interdepartmental committee, it is suggested that the secretary, administrative support and space be provided by DREA. It is also suggested that the position of chair rotate on an annual basis. To achieve continuity, a three-year sequence of responsibility is envisioned. Each year, the committee will elect an Assistant Chairperson position. That person will then succeed to the position of Chairperson the year after, and subsequently to the position of Past Chairperson the year after. Governance will thus be shared between three persons, with distinct responsibilities for each. It is suggested that agencies be required to provide for full time involvement of personnel during any year in which they serve as Chair, and half-time for the positions of Assistant Chair and Past Chair.

For policy guidance, the ECC will be directly responsible to the National Committee on the Environment (NCE).

The National Environmental Mapping Program

The National Environmental Mapping Program (NEMP) will be a decentralized program of coordinated mapping activities, designed to provide consistent and timely data in a format suitable for integrated analysis using Geographic Information System (GIS) technology.

Conversion of data into digital format will proceed independently within each of the responsible agencies (Surveys, Lands, Forests, etc.). However, to be designated as a NEMP node, certification will be required by the ECC. Certification requires the provision of a permanent member to the ECC, and the development of a digital mapping program that is consistent with the aims of the EIS. Such consistency will include the development of data models, standards and exchange formats that meet with the approval of the ECC as a whole.

EIS Distribution Center

Although each agency in the NEMP will develop digital data sets independently, distribution of those data sets will be through a coordinated network of EIS Distribution Centers (EDC). Initially, it is proposed that a single EDC be established within DREA. This will consist of a centralized set of data holdings and the equipment necessary to copy and distribute those data in a timely fashion.

For reasons of cost, speed and efficiency of distribution, it is suggested that serious consideration be given to the use of CD-ROMs as the medium of storage and distribution. In addition, procedures will need to be implemented to maintain the archival nature of these data sets. Current CD-ROM technology does not meet national archival standards. Thus a backup system of Exabyte tapes (30-year life) should be considered (or a regular program of remastering). At present, there is little reason to believe that such a system cannot be implemented using microcomputer technology. A single system with a gigabyte hard drive, two CD-ROMS and an Exabyte tape should provide adequate facilities in the initial stages of development. At a later stage, more systems can be added as necessary.

National Environmental Information Center

The National Environmental Information Center (NEIC) will act as a centralized one-stop source for information on the availability of data sets, how to acquire them, and advice on suitable technologies for their display and analysis, and educational programs about them.

Although in the initial stages, NEIC's information will pertain predominantly to data encompassed by the National Environmental Mapping Program, it is envisioned that a broader domain should be considered. For example, this center might provide information on air photo holdings, procedures for access to satellite imagery (Landsat, SPOT, AVHRR), holdings of imagery within various departments, documents, reports, and so on. The basic seeds for such a system are already in place at DREA and can be built upon to develop this center.

National Program for the Development of Environmental Information Technologies

To support the development and maintenance of the EIS, a National Program for the Development of Environmental Information Technologies will be required. In its initial stages, this should be developed through external donor assistance. However, it should progressively move towards the development of a national program run as a consortium activity of government and university programs. Ultimately, envisioned activities of this program might include:

- ***university and certificate programs in environmental information technologies***
- ***inter- and intra-agency professional training programs***
- ***secondary school educational programs***
- ***coordinated research opportunities for academic and government professionals to investigate critical issues in the use of environmental information technologies in the Malawian context***

Technologies encompassed by this program include (as examples) :

- ***Geographic Information Systems (GIS)***
- ***Digital Image Processing (DIP) of remotely sensed data***
- ***Global Positioning Systems (GPS)***
- ***Area Frame Sampling***
- ***Aerial Video Survey***
- ***Environmental Impact Assessment (EIA)***

To put structure to this set of technologies, it is proposed that one of the first tasks of the interim NPDEIS be to develop a Compendium of Environmental Information Technologies. This can then be used to structure educational programs and curricula in this area.

It is proposed that this program ultimately be managed as a University program, with a steering committee composed of representatives from a consortium of University and Polytechnical programs, DREA, and the ECC.

Procedures for the Development of the EIS

The initial requirement in the development of the EIS will be to gain government and donor support. Given the interest in consolidating the National Environmental Action Plan (NEAP), and current donor activity in the area of environmental monitoring, this should be possible to develop a multi-donor assistance program without too much difficulty. The next stage will then be one of Structural Organization in which the main organizing elements are put into place. Following this comes perhaps the most pains-taking part of the entire process -- System Design. There are a great number of details that need to be considered by each of the agencies involved in the National Environmental Mapping Program (NEMP). It is therefore proposed that the NEMP proceed with an provisional design, with ,re-evaluation after the EIS is in an operational mode. Finally, with provisional designs in place, all elements of the EIS can begin.

The following is a rough outline of this sequence of activities:

1. ***Gaining Government and Donor Support***
   Professional Level Technology Awareness / Applications Workshops
   Management Level Technology Awareness Seminars
   Formal Program Proposal and Acceptance

2. Structural Organization

Development of the interim ECC

Development of an interim NPDEIT

Development of the NEMP Coordinating Committees within Agencies

NPDEIT: Continued Professional Level Trainings

NPDEIT: Final Organizational Design

EDC : Organizational Design

NEIS : Organizational Design

3. System Design

NPDEIT: Development of the Compendium of Environmental Information Technologies

NEMP: Data Model Development

NEMP: Standards Development

NEMP: Digital Exchange Format Development

ECC: Formal Organization

EDC : Procedural Design

NEIS : Procedural Design

NPDEIT: Formal Program Design

4. System Implementation

NPDEIT: Implementation

NEMP: Physical Database Development

NEIS and EDC Implementation

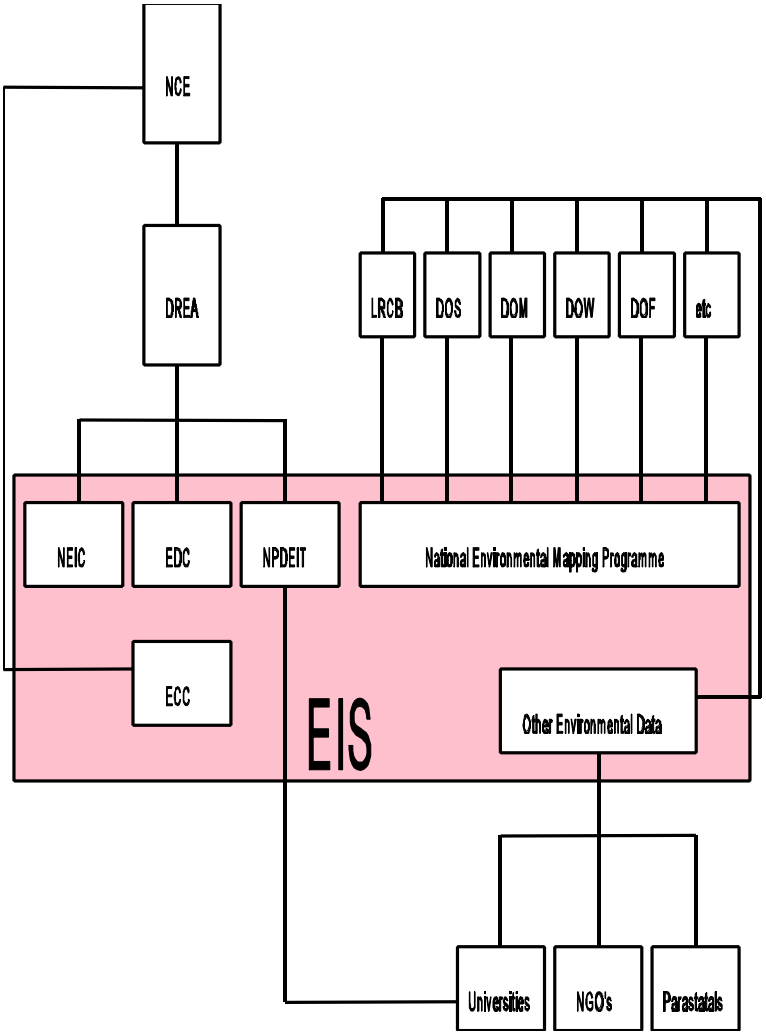

Figure 1 : ***The Environmental Information System***

NCE = National Committee on the Environment ***DOS = Department of Surveys*** ***DOF = Dept. of Forestry*** ***DREA = Department of Research and Environmental Affairs*** ***DOM = Department of Meteorology*** ***NGO = Non-Governmental Org.*** ***LRCB = Land Resources and Conservation Branch*** ***DOW = Department of Water*** ***EDC = EIS Distribution Center*** ***NPDEIT = Nat. Program for the Dev. of Env. Info. Technologies*** ***NEIC = Nat. Env. Info. Center*** ***ECC = EIS Coordinating Cmte.***

Appendix XI : Manual vs. Digital Landuse Mapping

This example demonstrates the use of new technologies for creating local-level landuse maps. Traditional landuse/landcover (LULC) mapping is performed using manual interpretation techniques from aerial photography. In many cases the use of this method can be quite adequate provided the appropriate aerial photographs can be obtained. The use of this technology, however, has its limitations, especially when larger scale mapping is required in areas of highly varied vegetation cover. In Malawi this is especially the case as the landscape is quite diverse and can not be generalized at such large scales. These two images show the results of using the two methods. Figure 1 shows the landuse map produced by LRCB using manual interpretation from aerial photography for the Kamunde Catchment in Central Malawi. Figure 2 shows the same catchment area but a LULC map produced from 20 meter SPOT satellite imagery. It is evident that the satellite imagery is able to capture the local variability and the patch-work landscape most often found in Africa.

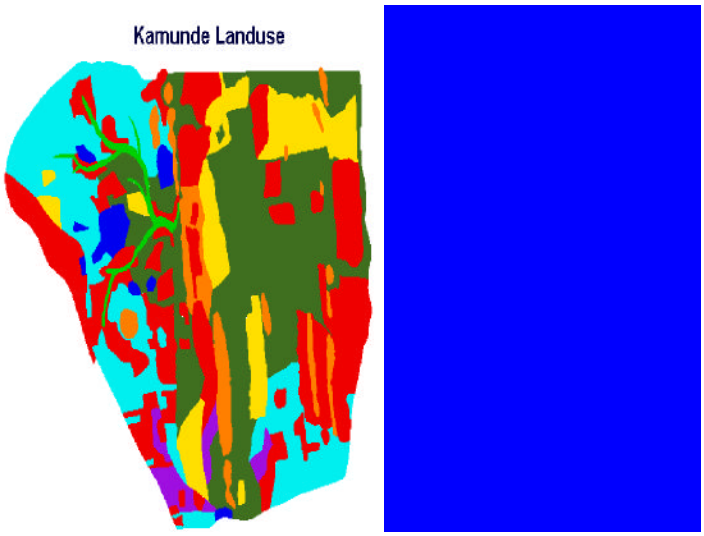

Figure 1 : Landuse map produced from manual interpretation from aerial photography.

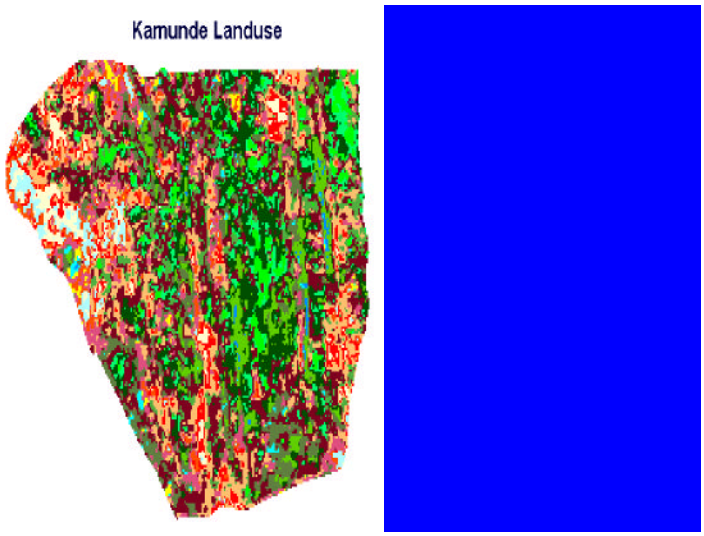

Figure 2 : Landuse map produced from digital interpretation from satellite imagery.